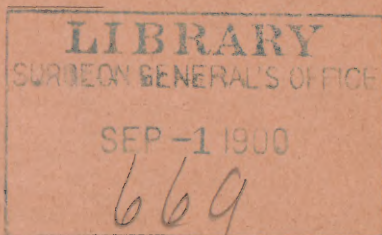


Wyman  
Regards of Morrill Wyman  
COTTAGE HOSPITALS

BY

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COTTAGE HOSPITALS.<sup>1</sup>

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THE Cambridge Hospital, which may serve as an illustration of the subject of this paper, is situated about one mile west of Harvard College, on the south side of Mt. Auburn Street. The site has 9 1-3 acres. The soil is dry and gravelly; it has few trees, but is well covered with grass. The surface upon which the buildings stand is well raised above the crown of the street, is about 25 feet above the level of Charles River and 600 feet from its left-bank, along which it has a water front of 500 feet. On the opposite bank is a park or meadow of 100 acres, of which 70 acres were given by Prof. Henry Wadsworth Longfellow and others to Harvard College "to be held," so says the deed of gift, "by the grantees as marshes, meadows, gardens, public walks or ornamental grounds, or as the site of college buildings not inconsistent with these uses"; the other 30 acres were given to Harvard College by Major Henry Lee Higginson to be called the "Soldier's Field." The river in front, here about 250 feet wide, and the meadow beyond effectually exclude all dust, smoke and noise from that direction. The view to the south is unobstructed quite to Corey's Hill, two miles away. The whole forms a scene the equal of which in beauty and fitness for the purposes to which it is consecrated it would be hard to find. Longfellow and Lowell have sung of the "Silent River" and its meadows.

The hospital buildings are a centre and two wings or wards, the three forming a hollow square with the

<sup>1</sup> Read before the Cambridge Society for Medical Improvement, March, 1895.



opening towards the south ; a corridor, also facing the south, joins the two wards. This corridor is glazed in winter. With this orientation each ward receives the full influence of the sun and the free course of the very desirable southwest breezes of summer.

The ward to which the following observations refer is 60 feet by 30 feet, and 12 feet high, the ceiling higher in the middle than at the walls, with 21,000 cubic feet of space, giving 113 square feet of flooring and 1,356 cubic feet of space for each patient. It has five windows on each side. At the south end is the sun-room, 8 feet by 30, open or glazed as the season may require. The 16 beds in each ward (the hospital has 40 beds) are arranged with the head next the wall and about one foot from it, well out of the way of direct currents. Beneath each bed is an eight-inch pipe which rises about three inches above the floor and is connected beneath it with a foul-air duct leading to the ventilating chimney of 16 square feet area and 60 feet in height. The other ventilating apertures are the windows, of about 20 square feet each, with movable sashes, double in winter, with a deflecting board above the upper sash for the better distribution of the incoming air. Each of these windows gives, when open, an area of nine square feet. There are two openings in the ceiling of about 10 feet area each ; in the middle of the ward is a chimney with fireplaces on two of its sides. They are frequently used in the mild weather of spring and fall. Above the ceiling are two trunks for ventilating the attics, and 14 openings on the sides, just beneath the eaves, and protected from the rain ; when open in summer these openings allow of the free movement of the winds over the floor, materially cooling it and the ceiling below.

Beneath the ward and extending under the whole of it, is the air-chamber ; it is eight feet high, two and a half feet of which is above the ground ; it has 16

windows of four square feet each, giving sunlight and air to every part; it has also a doorway of 40 square feet, the whole giving 100 square feet of openings for air. The walls are of stone and mortar, with a carefully-made cement floor, well smoothed. This is exclusively an air-chamber. It contains only the heating-boxes and the flow and return pipes connecting them with the two boilers in the administration building. There are 10 of these heaters of about 18 cubic feet each, set close under the ward floor; they contain the cast-iron radiators, each with 30 square feet of heating surface, known as Gold's pin radiators, through which the hot water passes, entering at the top and going out at the bottom on its way from and to the boilers. The moving force is due to the difference in temperature, which causes a difference in density in the balancing column of water, in the flow and return pipes. This difference of temperature is  $40^{\circ}$  to  $50^{\circ}$ ; the flow pipe is about six feet above the return. The air enters these heating-boxes from the air-chamber, or, directly from the outer air through ducts controlled by valves, and enters the ward through 10 registers of 1.5 square feet each about 18 inches from the floor, one beneath each window, which is between each two beds.

The ward floor is of two-inch planks supporting a hardwood floor; it is what is called a mill or slow-burning "Swiss" floor; it has no plastering or enclosed space of any kind below it.

The air-chamber is kept scrupulously clean and free from dust; no furniture nor anything else is allowed in it under any pretence whatever. Its office is solely to receive fresh air and distribute it to each of the ten boxes, in equal quantity to reach the ward unchanged in every respect except in temperature. This may be criticised as a waste of room, but we know to what base uses cellars are generally put and the effect they

might have upon the ward above. This chamber is lighted by direct sun-light; it receives air freely; it is surrounded by gravel; it is dry; and it secures nearly all, if not all, the advantages claimed for buildings standing upon piers above ground, with the additional advantage of controlling the admission of cold air in winter, essential in this climate. The equal distribution of the air to each of the ten registers can hardly be so well secured in any other way. It is for these reasons that the air-chamber has been so constructed, and its eight years of use have proved its value.

The bed, in which most of the days and nights of the hospital patient is spent from entrance to convalescence, is worthy of careful consideration. It is to the bed that most of the hospital arrangements refer. Its place, as regards windows for light and air, its distance from the wall to avoid down-draughts, its height and breadth for convenience of nursing, and its ventilation must all be cared for. Its coverings must be light, warm, and the more air there is in their folds and meshes the warmer they are; the under-beds of hair or vegetable fibre, must be porous that air may pass through them, and elastic that they may bend to and properly support the unequal pressure of the body.

The bed is a piece of apparatus with a system of warming and ventilation of its own, as necessary and as complete, in its way, as the ward in which it stands. The body warms the bed, its coverings and its contained air, and this in turn the entering air. The heat is always on the move upward and outward. If any one will take the trouble, his thermometer will show that the fresh air enters at the sides, is warmed by contact with the body, rises through the successive layers of coverings, which delay without arresting its progress, until it reaches the surface, leaving the outer covering instead of our sensitive peripheral nerves to



fight for us our battle with the surrounding cold. But this is not all; the bed-clothes, if porous, allow the passing air to carry off perspiration and the other skin secretions, miscible with it, which if retained saturate the clothes and cause uneasiness in the skin and general discomfort.

More or less air enters the bed from beneath, as well as at the sides. The space beneath the bed, therefore, must be kept scrupulously clean and the air pure. Each bed has, to this end, an outlet in the floor, connected with a duct beneath it, leading to the main ventilating chimney; the coverlet falls no lower than is necessary to prevent its too easy displacement, but not so low as to prevent the free movement of the air and the ready inspection of the whole floor beneath.

The sick take less food than the well, they sleep more, they consequently make less heat; furthermore their horizontal position favors the escape of the warm air around them; for these reasons their heat in winter should be economized, their clothing warm, and the weak, especially the aged, who make but little heat, have hot-water bottles at their sides, not so much to warm their bodies by actual contact as by intercepting and warming the incoming air before it reaches the body and keep up the peripheral circulation so that the internal heat-making organs may have less work to do.

By the arrangements just described the bed is of necessity ventilated into the ward. But sometimes the bed itself is filled, and the clothing impregnated with offensive gases, which moved by the heat of the body and the respiratory motions enter the ward and contaminate the air in the vicinity to a degree that no general ventilation of the room can at once remove. To prevent this, a pipe two inches in diameter may be led from any part of the bed down into the opening beneath the bed. By this simple device foul air is drawn from the bed or bed-pan and fresh air from the

ward properly warmed in the way just mentioned — if need be, substituted. This done, the patient is no longer surrounded by a tainted atmosphere ready to be inhaled or absorbed by abraded surfaces, nor the air of the ward contaminated.

The patient no longer an object of disgust, isolation in a separate room is unnecessary; otherwise, in spite of deodorizers and antiseptics, the vicinity may become absolutely intolerable. Isolation increases the expense of treatment and the number of nurses; and what is more, it deprives the wretched sufferer of what comfort he can get from association, a comfort that no hospital should overlook.

It is in this way that the bed has its own system of heating and ventilation.

This system has been applied to all the bath-tubs, water-closets and sinks. All these have in common a soil-pipe of six inches diameter, with two running traps — one at the closet and another outside the hospital building. Between these traps the soil-pipe has a branch air-pipe of the same diameter, reaching to the top of the chimney, sixty feet high. This air-branch is surrounded by a jacket ten inches in diameter, which receives all the waste heat from the kitchen fire. This secures a constant in-draught from all points with which it is connected, or from leaks or cracks in the soil-pipe. It is connected with the hopper of the water-closet by a short two-inch pipe, never larger (like that for the bed), that passes round the trap into the soil-pipe and from that into the air-branch.

The common cold-air ventilating pipe in our houses, going through the roof, has no draught; it relieves pressure between the traps, but has no effect upon parts outside the traps, from which very bad odors often flow into our rooms. This hospital arrangement, with the two-inch connecting pipe always in action, keeps the water-closet and all its connections free from



odor at all times, even when in use, while the large soil-pipe rapidly discharges the contents of the hopper and its wash into the common sewer. All fluids and solids go to the sewer, and all gases and odors to the chimney-top. As with the bed, this also is one of the few instances in which we can seize the evil at its source and quickly and effectually dispose of it. This method of ventilating privies with a fire is by no means new; it was used in the fourteenth century at Pierrefond, in France, where there are three privies, one in each story, connected with an air-tight vault under ground and a heated chimney going through the roof.<sup>2</sup>

Preparatory to ventilation we must have cleanliness of walls and floor. Every part of a ward that can be reached with water and soap or with a wet cloth must be cleaned. No dusting allowed; that only takes dust from one part to scatter it over all others. The coverlets of the bed must be shaken in the open air. The secretions and transpiration of patients removed as soon and as completely as their conditions will allow. At the Cambridge Hospital the floors are every morning first strewn with moist sterilized red-cedar sawdust, which is both cleanly and fragrant, and then carefully swept. By this means careless sweeping is betrayed and its consequences prevented. Ventilation begins where what is commonly called cleanliness leaves off.

Ventilation is the removal of foul air by the introduction of that which is pure from the open, generally without change except in temperature.

At the Cambridge Hospital at those seasons when the ventilation is principally by the registers, air from the air-chamber enters the ward by the ten registers already described, nearly horizontally between and parallel to the beds, rises towards the middle of the ward until it meets that from the opposite register,

<sup>2</sup> Viollet-le-Duc's *Architecture: Latrines*.

when its direct motion is lost in eddies and various movements mingling and moving with the foul air until it is practically distributed through the whole ward; the mixture finally escapes through the floor openings into the foul-air ducts leading to the ventilating chimney, or by the ceiling ventilators into the atmosphere. It is a constant process of dilution of foul air by pure air, to which the diffusive property of gases lends aid, and the steady removal of the mixture. This dilution is the great principle of ventilation; foul air can seldom be displaced in mass. The quantity and direction of air coming into the ward are controlled at each register.

The following table shows the amount of air for winter ventilation entering the ward each second and each hour for each of the sixteen beds.

The air is measured by a Casella's air-meter at the register, reduced, for convenience, to a square foot, care being taken to get the average velocity by measurement in different parts of the current, and taking care that the air which has passed the instrument has a free escape.

The first column shows the cubic feet in one minute as actually observed at each of the ten registers, the second column the cubic feet in one second, and the third the quantity distributed to each of the sixteen beds in one hour. The observations were made in January and February, 1894.

The extremes in the last column were 6,500 and 10,000. These variations are not greater than may be expected in observations of this kind; they are due in part, perhaps, to the observations, but principally to changes in the force of the wind and the arrangement of the windows of the air-chamber; 10,000 was observed during a brisk wind, the other observations were made on calm days. The "flushings of the wards" to be described further on are not included in this table.

In these investigations the air entering through the registers has alone been measured. No reference is had to that coming by other ways, around doors and windows and the innumerable cracks and crevices. This is much greater than is generally supposed. In

VENTILATION IN WINTER MEASURED BY CASELLA'S AIR-METER.

Date.	Cubic Feet of Air for			Temperature.			Observations.
	Each of 10 registers, per min.	Each of 16 beds, per sec.	Each of 16 beds, per hour.	Ward register.	Ward.	External.	
1894, Jan. 26	201	2.1	7,500	116°	68°	16°	Eight.
Feb. 6	229	2.3	8,200	103	69	16	Five.
Feb. 7	185	1.9	6,800	116	70	..	Four.
Feb. 12	213	2.2	7,900	112	71	28	Five.
Feb. 12	225	2.4	8,600	110	71	..	Nine.
Feb. 12	218	2.26	8,100	..	71	..	Five.
Feb. 19	193	2.	7,200	112	69	46	
Feb. 22	267	2.8	10,000	109	68 }	22	
Feb. 24	255	2.6	9,100	109	71 }	12*	
Feb. 26	221	2.3	8,200	120 }	68	23	
Mar. 26	250	2.5	9,000	118 }	..	32	
Mar. 26	180	1.8	6,500	110	..	32	

\* At 2 P. M.; 7° at sunrise.

a room warmed by a hot-air furnace, with an outside temperature of 33° F. and the incoming air at 108° to 129°, it was found that with the greatest care in stopping all cracks and crevices about windows, doors and keyholes, oiling and painting the woodwork and plastering, the air entering by the register was



diminished but 20 per cent.<sup>3</sup> Assuming the same state of things at this hospital — and, under the inward pressure caused by the ventilating chimney, it can hardly be less — the total amount of air entering the wards was 20 per cent. greater than that measured at the register.

The permeability to air of our plastered ceilings is well seen in a room where there has been smoke; the dark streaks show that the smoky particles have been strained out; the lighter color is where the furrings above have obstructed this outward movement.

Pettenkofer, from his own observations on the porosity of building materials, finds the amount of ventilation through the walls of his room of 2,648 cubic feet, for a difference of temperature of 18° F. between the inside and outside, to be at the rate of 8.65 cubic feet each hour for 10.85 square feet of wall surface. Many experiments have been made on the porosity of the walls of stone buildings, with the result that they are more porous to air than is generally supposed.

The ventilation here indicated in our table appears large when compared with that generally given in hospitals. Those recently built have been much more liberally supplied with air than formerly, but the improvement in this respect has been slow. Until thirty years ago it was thought that about 1,000 cubic feet an hour for each bed was sufficient. In 1860 Lariboisière Hospital in Paris was built, its plan — the pavilion plan, as it is called — has been followed in the construction of this and most of the best hospitals. An investigation made at that time showed that a ventilation of 2,480 cubic feet an hour for each bed did not always prevent a disagreeable organic odor in the wards. It was afterwards assumed that for hospitals in general 2,840 feet an hour was sufficient, and for

<sup>3</sup> Mr. J. Pickering Putnam : The Open Fireplace.

wounded and surgical cases 3,550 feet. Dr. J. S. Billings, in his excellent and exhaustive treatise on ventilation, recommends 3,600 feet an hour — one foot a second.

At Johns Hopkins Hospital, from Dr. A. C. Abbot's report, it appears "that during those months in which the occupants of the wards are in the main dependent upon the register for their fresh-air supply, each individual receives at least one cubic foot of fresh air per second, and usually a little more."<sup>4</sup>

In inquiries of this kind it has been assumed that four per cent. of the expired air is carbonic acid, and that the percentage of the same gas found in the ward over and above that normally belonging to the open air is an index of impurity; not that this amount of carbonic acid found in hospitals is necessarily unhealthy, it is used merely as an index of the organic impurities generally thrown off from human beings, which cannot be properly estimated by chemical methods.

The results obtained by different observers, however, are by no means identical. Of some of the conditions of the air in the wards carbonic acid can be no indication, such as the relative humidity, the dust, the number of bacteria and some of the products of combustion. It can only be a measure of those impurities that produce carbonic acid. After all, this question belongs not so much to chemistry as to physiology and inasmuch as it relates to the sick, to pathology also. It must be remembered that a deficient or vitiated air-supply may act very differently upon the sick and debilitated than upon those who make investigations on this subject in chemical laboratories.

It has seemed, therefore, better to attempt the solution of this very important question by studying, in our wards, the condition of the sick with a much

<sup>4</sup> Johns Hopkins Hospital Bulletin, September, 1891, p. 131.

larger air-supply than is commonly given. The construction of the Cambridge Hospital is such that it is possible to do this with a reasonable hope of success.

In determining the proper quantity of air, care has been taken not only to meet all the requirements as to temperature, the only respect in which it differs from outside air, and its character as measured by carbonic acid, but an attempt has been made to go further and give that quantity of air, whatever that may be, that experience shows is required for the comfort of the sick and the prevention of all organic odor. It is not asserted that this desirable point has at all times been reached; in some instances it has not, and yet while some of our best hospitals have deemed less than one and a half cubic feet a second sufficient, it has been found in Cambridge Hospital, that to attain the degree of purity indicated by the entire absence of all animal odor, two feet a second, at least, for each bed has been required, and something more than this has been aimed at and generally given.

The movement of the air about us, and it is never still, the natural ventilation, as it is called, is much greater than is generally supposed.

Faraday's experiments show that at two feet a second (Pettenkofer says at one metre a second) we first begin to feel the air as a moving body. At one-half or one-third of a metre a second we consider it a perfect calm; our senses are not delicate enough to recognize it, and yet air at that velocity would move from end to end of the Cambridge wards in thirty seconds, and across them in half that time quite unnoticed by us.

Taking Pettenkofer's illustration: Suppose a frame of the size of a man, six feet by eighteen inches, nine square feet. Now, with this inappreciable velocity of two feet a second, 18 cubic feet would pass through this space in one second, or 1,000 cubic feet a minute;



to this 1,728,000 cubic inches a man would add by respiration in the same time but 14.4 cubic inches of carbonic acid or one part in 12,000. This measures, under these conditions, the rate of nature's method of diluting the carbonic acid produced by respiration.

Human beings are so constituted that they can resist to a certain extent the noxious agents to which they are constantly exposed, otherwise a single bacterium might prove fatal, or the spread of contagium be unlimited.

Lister, early in his investigations, pointed out that the tissues of the body must exert a powerful bactericidal effect in many wounds and after operations of small extent to which bacteria gain access in considerable numbers. The human saliva and the adenoid tissue of the tonsils, and that about the esophagus, are believed to have this bactericidal effect, the active cells even coming out from the tissue to get within striking distance of the approaching bacteria.<sup>5</sup>

It is the object of ventilation to remove or so dilute unavoidable and constantly recurring impurities that they may come within the limits of this bactericidal influence.

Although carbonic acid is held by many to be an index of the pollution of air in closed rooms, it cannot, as already said, be accepted as an index of the amount of dust or the impurities that do not produce carbonic acid, yet dust of various kinds and bacteria are found in hospitals by the microscope and the koniscope of Atkins in bewildering numbers. With the latter instrument the products of combustion have been demonstrated to have spread 24 feet from their source in less than 35 seconds after striking a match to light

<sup>5</sup> Dr. Sims Woodhead on Channels of Infection in Tuberculosis. London Lancet, November 17, 1894, p. 957.

Dr. E. M. Buckingham on Medical Treatment of Diphtheria, Importance of Open Air. Boston Medical and Surgical Journal, February 14, 1895, p. 147.

the gas in a room of over 5,000 cubic feet of space; showing the movements of air and the delicacy of the test for these kinds of impurities.

R. Stern, of the Hygienic Institute of the University of Breslau,<sup>6</sup> has made some valuable experiments on the influence of ventilation on the numbers of organisms, either alone or attached to and riding about on particles of dust floating in the atmosphere, and has come to these results: when the air was perfectly still, the dust and bacteria thrown into the room prepared for his experiments, sank quickly to the floor; when ordinary dust from library shelves was employed, the air was almost entirely free of bacteria in an hour and a half. "The lowest limit of ventilation that caused an appreciable acceleration in the disappearance of germs from the air was an exchange of from six to seven times an hour of the whole volume of air in the room"; except by very strong winds bacteria were never driven from moist surfaces.

From a consideration of these conclusions Stern feels justified in recommending as a means of disinfecting rooms which have been occupied by persons suffering from infectious diseases, that as soon as the patient has been removed, the room be closed and allowed to remain so for at least twenty-four hours, after which, it should be quietly entered, and the floor, wall surface and furniture mopped with cloths saturated with corrosive sublimate 1 to 1,000. Under no consideration is dusting to be countenanced.

In connection with Stern's paper, it may be again stated that the winter ventilation of two feet a second at the Cambridge Hospital dilutes the air of the ward with an equal quantity of fresh air six times an hour. The summer ventilation is much larger.

Air is not chemically or physically pure; it contains beside its normal constituents something from the

<sup>6</sup> Johns Hopkins Hospital Bulletin, vol. 1, p. 15.

various objects or gases with which it comes in contact. Water which is claimed to be pure, healthy drinking-water is not, and ought not to be, chemically pure; but if it contain visible impurities, it cannot be regarded as good drinking-water. So the air of our wards may vary in many respects as to its chemical and physical constituents, but if it has an evident animal odor, it cannot be regarded as good breathing-air.

It is certain that expired air and the exhalations of the skin contain organic matter of an unknown nature, of offensive odor, which when existing in considerable quantity causes discomfort and oppression, and have to those examining ventilating ducts proved actually poisonous without other known change than that detected by the sense of smell.

It may be accepted on good authority that the amount of carbonic acid in the air is no certain index of the quantity of organic matter in it; nor does the process with the permanganate of potassium solution, which requires considerable time and much apparatus, prove satisfactory.<sup>7</sup> It is quite unfitted for use by those upon whom the management of hospitals usually falls. We must seek for the desired test elsewhere than in chemistry.

The question belongs to physiology; chemistry does not teach physiology. The sense most readily affected by the air of our habitations is that of smell; it is the one first appealed to. No competent observer would consider a ward well ventilated which has a distinct musty or animal odor, whatever may be its other conditions.

Dr. De Chaumont, who has made many observations on the condition of the air as indicated by our senses, found that air with a temperature of 63° F., which has no animal odor and is called "fresh," does not contain above two volumes of carbonic acid in 10,000 due to respiration.

<sup>7</sup> Ventilation and Heating, by John S. Billings, M.D., p. 200.



Humidity, inasmuch as it intensifies the effect of odors, adds still more value to the sense of smell as a guide to good ventilation. We know well that the evening air, which, as a rule, is moister than the day air, has great influence in bringing out the perfume of flowers. Man has not the wonderful sense of smell of some of the wild animals, and yet there are few persons who fail to recognize the sea breeze by this sense before it can be demonstrated by chemical methods or instruments of precision.

It may be objected that this sense varies with different individuals and with the same individuals at different times. This is true. The testimony is of the class of subjective symptoms, but it is from this class that we draw the testimony upon which much of our medical reasoning is founded. Physiological and pathological problems must be investigated and solved by physiological and pathological methods. Some of the specific diseases have a peculiar odor of diagnostic value to the experienced physician.

Leaving out of consideration, then, those tests requiring a laboratory and chemical experts, which can seldom be obtained in our hospitals, and not forgetting its limitations, this sense affords us practically one of the best, if not the best, single test we have; it is a good common-sense test. It is well to adopt it, at least until a better is found, for, whether we do or do not, it is the test our visitors will apply, and if just from the open air, it acts with full force, and upon it they will rightly ground an opinion as to the cleanliness of our hospitals. It will be hard to find one who perceives in the air a musty or animal odor who will say, "This is good, fresh, breathing air." It is the reverse; the continuous breathing of air containing such odor is unhealthy. The nurses at Cambridge Hospital are enjoined, when going from the open into the ward, to notice the difference in smell, and to set their ceiling

ventilators accordingly, and if necessary put the fan in motion, which should soon restore the air to its proper condition.

The following determination of the relative proportion of carbonic acid in the wards of the Cambridge Hospital, March 16, 1894, we owe to the kindness of Dr. Theodore William Richards, Assistant Professor in Chemistry in Harvard University.

The air was taken with bellows from the middle of the ward and blown into the bottles standing on the ward table, care being taken to avoid anything from the breath of the collector; the bottles were stopped with paraffined corks.

The number of volumes of carbonic acid in 10,000, as determined by Pettenkofer's method, was as follows:

Bottle No. 1	.	.	.	.	.	.	.	.	7.1
Bottle No. 2	.	.	.	.	.	.	.	.	5.9
Bottle No. 3	.	.	.	.	.	.	.	.	6.5+
Mean,	.	.	.	.	.	.	.	.	6.5

Prof. H. B. Hill has determined, as the mean of eleven observations, that the proportion of carbonic acid in 10,000 in air taken 20 feet north of Boylston Hall in the "College Yard" is 3.39; deducting this from 6.5, the mean of Dr. Richards's determination, we had at that time in the ward 3.1 volumes in 10,000, as the excess of the carbonic acid in 10,000 above the normal. The air entering the ward at the same time was the usual winter supply of 2.2+ feet a second for each of the sixteen beds.

The cost of heating large quantities of cold air is a very important matter to those interested in the management of hospitals. The general heating of the Cambridge Hospital is by the hot-water system. The space heated includes the two wards of 64,000 cubic feet, with the ventilation as above described, and the Administration Building of 60,000 cubic feet, with

ordinary house ventilation. The boiler fires are lighted in the last week of September and put out the last week in May. The coal burned during eight months' firing (average of three years) was 75 1-2 tons.

TEMPERATURE OF WATER IN THE BOILER AND RETURN PIPE  
AND COAL BURNED IN DECEMBER AND JANUARY, 1887-88.

*Temperature.*

	Coal lbs.	6 A. M.		12 M.		6 P. M.	
		Boil.	Ret.	Boil.	Ret.	Boil.	Ret.
Dec. 20, . . .	800	148°	100°	180°	138°	186°	132°
21, . . .	800	150	102	184	130	180	130
22, . . .	800	160	110	186	132	192	138
23, . . .	1,000	138	100	192	140	186	138
24, . . .	1,000	160	110	200	140	200	140
25, . . .	1,000	150	110	200	142	200	142
26, . . .	800	140	110	200	140	200	144
27, . . .	1,000	140	106	206	146	210	144
28, . . .	1,000	150	110	210	148	210	162
29, . . .	1,000	170	120	210	160	202	160
30, . . .	1,000	170	120	208	162	210	152
31, . . .	1,000	170	120	206	160	210	158
Jan. 1, . . .	800	150	118	210	148	206	150
2, . . .	800	140	95	200	140	206	152
3, . . .	800	150	110	200	142	208	160
4, . . .	800	136	106	210	152	198	140

NIGHT TEMPERATURE OF WARDS.

1888. Jan.	8	10	11	12	13	14	15	16	17	18
8 P. M.	73.5°	73°	71°	68°	75°	77°	77°	71°	70°	74°
9 "	72.5	71.5	68	70	74	75	72	..	69	73
10 "	71	70.5	65	74	71	71	70	68	68	71
11 "	70	69.5	61	70	70	69.5	68	70	68	69
12 "	70	68.5	63	64	68	69	69	71	67	71
1 A. M.	70	67.5	65	63	69	68	70	71	68	71
2 "	69	66.5	62	62	68	66	68	71	68	69
3 "	68	68	60	63	69	66	65	71	68	68
4 "	68	70	60	64	70	66	66	70	67	66
5 "	67	65	62	64	69	69	67	70	69	64
6 "	66	60	64	70	69	69	70	70	70	66

COAL BURNED UNDER THE BOILERS FROM APRIL 1, 1887, TO  
APRIL 1, 1888.

	Tons.
April, 1887 . . . . .	2.75
May . . . . .	2.75
June . . . . .	.6
October . . . . .	4.75
November . . . . .	9.
December . . . . .	11.7
January, 1888 . . . . .	19.25
February . . . . .	13.6
March . . . . .	11.1

75.50

The preceding tables give the temperature of the heating boilers and of the return pipes, with the night temperature of the wards; the amount of coal burned in the months of December and January, the two most expensive months; and, what is of great interest in a charity hospital, the quantities burned during the whole period of firing.

The following table of temperature and relative humidity of the ward is given for March and a part of April, 1894. The readings of the wet and dry bulb thermometers were taken from Prof. Joseph Winlock's hydrophant; its place was on a shelf in the ward

RELATIVE HUMIDITY BY WET AND DRY BULB THERMOMETERS.

				<i>Ward.</i>			<i>Outside.</i>		
1894				Wet	Dry	R. H.	Wet	Dry	R. H.
March	5,	.	.	60°	71°	49%	44.4°	36°	29%
	6,	.	.	60	71	49	49.9	60	44
	7,	.	.	62	71	58	42	56.5	17
	8,	.	.	60	70	52	38	42.3	62
	9,	.	.	58	71	43	37	41.5	61
	12,	.	.	50	69	47	38.5	46.2	43
	13,	.	.	56	67	47	38	46	40
	14,	.	.	57	68	47	36	39	64
	15,	.	.	55	69	35	31	38	51
	16,	.	.	58	69	47	38	39	86
	17,	.	.	58	69	47	37	45	39
	18,	.	.	63	73	54	46	55	44
	19,	.	.	67	76	60	57	63	65
	20,	.	.	60	74	39	37	50	18
	21,	.	.	58	68	51	31	42	20
	22,	.	.	58	70	44	43	51	40
	23,	.	.	58	70	44	38	38.2	98
	24,	.	.	55	67	41	27	36	21
	25,	.	.	60	71	49	49	44	64
	26,	.	.	55	66	44	27	32	50
	27,	.	.	52	66	32	21	26	40
	28,	.	.	53	67	34	24	31	36
	29,	.	.	53	63	47	35	36	95
	30,	.	.	55	68	38	32	38	45
	31,	.	.	54	64	48	40	51	25
April	1,	.	.	60	70	52	49	61	33
	2,	.	.	56	70	36	35	45	27
	3,	.	.	53	67	33	26	33	37
	4,	.	.	56	67	46	42	47	66
	5,	.	.	60	73	42	48	57	44
	6,	.	.	58	70	44	36	40	65
	7,	.	.	56	69	39	33	43	21
	8,	.	.	57	69	43	34	34	100
	9,	.	.	55	67	41	32	34	74



without any whirling or swinging; a part of the time it was over the ventilating opening in the floor, where it was exposed to a good draught; no material difference between these two places was noted.

The table of temperature and relative humidity of the outside air is, by the kindness of Prof. Edward C. Pickering, Director of the Observatory, taken from his record.

There is much difference of opinion as to the proper percentage of humidity for health. In the open air it must always be considered with reference to its temperature. In this hospital, where the temperature varies very little from  $70^{\circ}$ , the average percentage through the winter was 43.6; in a sitting-room warmed by an open wood-fire in a house with halls warmed moderately by a hot-air furnace the humidity through the winter was about 60%.

The preceding table is given as indicating the physical condition of the hospital; no attempt is made to change this condition by artificial means; in summer it must necessarily be that of the outside air.

The motive power for winter ventilation is the difference of temperature, within and without, together with warm air from the wards at  $70^{\circ}$  which reaches the ventilating chimney through the foul-air ducts (losing less than  $10^{\circ}$  of heat on its passage), and the waste heat from the boilers and kitchen. In the late spring and early fall the heat in the ward chimney and kitchen, in which a good fire is kept up night and day, and the windows, have done fairly well for a great part of the time. Although the air entering the windows even in what seems to us a calm, is much greater than one would suppose, its distribution is unequal and very different in this respect from that which comes in by the ten allotted channels. Neither at times is the weather suitable, or air movement enough, for the proper flushing of the ward.

Then again in the heats of summer, in the hot sultry weather without a breeze, the sick are liable to suffer, in a manner depressing to both mind and body. This requires a much larger ventilation than has yet been considered.

In the Cambridge Hospital the principal motive power in summer is the fan. It is what is known as the heliacal or "screw" fan, 36 inches in diameter. It is set in the side of the air-chamber, firmly fixed by wedging tightly into the brick door-jambs in the wall, without connection with any resounding woodwork. It moves quietly, and produces no other sound than that of the cutting of the air by the blade — a slight buzz. It makes 500 revolutions a minute, and is driven by an electric motor of 500 volts — about three horse power. It has an air-moving power of 10,200 cubic feet a minute, and is equally well fitted to exhaust as to propel, but it is more convenient to use it as a propeller.

The air is taken in at about the same height above the grass-covered lawn around the hospital as that for the winter ventilation, and pursues the same course through the air-chamber, heating-boxes and register into the ward. The pressure on the air-chamber, when its windows and doors are closed, and the ten ward registers alone open, is about one-tenth of an inch of water, as measured by an anëroid barometer. In the following table is the amount of air delivered in the ward by the ten registers at the dates named during the summer of 1893 :

AIR DELIVERED BY HELIACAL FAN,  
(36 inches in diameter, 500 revolutions a minute).

1893	Each of 10 registers, cub. ft. per min.	Each of 16 beds, cub. ft. per sec.	For whole ward, cub. ft. per hr.
July 22,	662	6.9	397,000
Aug. 30,	687	7.1	412,000*
Sept. 2,	650	6.1	390,000†

\* Average 4 observations.

† Average 5 observations.

No doubt a certain amount of force is lost by using the whole air-chamber as a duct for reaching the several heating-boxes. So would force be lost by the resistance offered by the walls of multiple ducts for the same purpose; a loss that increases with their surface and length and as the square of the velocity of the air passing through them. Another and still greater objection to long air-ducts, is the difficulty of keeping them clean. Of this we have full evidence in the constant accumulation of dust in various forms in our foul air-ducts, requiring more frequent cleaning than one would suppose. The cleaning is a very troublesome matter even in those ducts large enough for the cleaner to creep through. On the other hand, every part of the air-chamber is open to inspection, and accessible with proper cleaning appliances. Again, the transmission of sound from the fan through metallic and wooden ducts has sometimes been found objectionable. Undoubtedly, the loss through the walls is considerable.

The table shows that six cubic feet a second is delivered to each bed; three times that given in winter. In its course as already described, this large quantity of air draws along with it much air from its immediate vicinity, and materially aids in its distribution through the ward. In the winter, as already said, the wards are more under the influence of the ventilating chimney, and air finds its way by a multitude of other passages besides the registers; in the summer when the fan is at work, the wards are more or less under pressure from without, and only that entering by the registers is to be considered in estimating the ventilation. This table shows that a quantity of air equal to the whole capacity of the ward, 21,000 cubic feet, is poured into it twenty times an hour.

It is sometimes questioned whether the movement of these large volumes may not cause draughts injurious to the sick.

The registers are so arranged that no bed is in the direct draught. We have a good illustration of the distribution of air through a room in the common hot-air furnace. The warm air from a register in the floor at first rises directly upward, drawing with it more or less of the surrounding air until it reaches the ceiling, where its current is diverted and more or less equally distributed through the whole room. It is not the current, but the diffused warm air that reaches us.

So of the ward, it is the general air of the ward, with a movement inappreciable by the senses, that reaches the sick.

The injurious effects of draughts probably depend for the most part on difference of temperature caused by the unequal or one-sided cooling of certain portions of the body only; if there is perspiration this local influence is still greater. These effects are first felt by the vaso-motor and sensitive nerves of the skin, disturbing its circulation in the first instance, and then spreading and throwing into confusion the nerves of other parts, and even reaching the circulation of the internal organs. This confusion does not happen when the whole body is equally exposed to the same influence, even if it is a wind.

A one-sided radiation from our bodies when near a cold wall or a cold closed window may cause a sensation as objectionable as that of a draught of cold air from them, and is often mistaken for one.

The most important general ventilation is "the flushing of the wards." Formerly when this was in process, the greater part of the air entered through the large windows at the end of the ward, passing through its middle to the opposite end, while the beds, which are near the walls, are quite out of the way of the first movement but enjoy the full benefit of the general change of air which follows.

The fan now does the greater part of the "flushing"



through the ten registers. In cold weather very large volumes of warm air are thrown into the wards for a short time, the heat of the boilers being temporarily increased for this purpose. Although the temperature of this large quantity of incoming air may be somewhat lower than that ordinarily supplied, that of the walls is practically unchanged, and on stopping the fan the air soon regains the degree it had when under the influence of the ventilating chimney alone.

The fan is so valuable an agent in supplementing the chimney and so readily meets the varying condition of the atmosphere, that without it the equipment of the Cambridge Hospital would be incomplete.<sup>8</sup>

The summer ventilation, as already said, is three times that of winter; it dilutes the air of a ward with an amount equal to its capacity, twenty times an hour. It carries away so much of whatever is diffusible or miscible in the air that the relative organic or chemical impurities remaining as measured by the proportion of carbonic acid, compared with Dr. Richards's determination in winter (6.5 in 10,000 volumes), does not add one volume in 10,000 to that normal to the atmosphere in Cambridge, as determined by Prof. H. B. Hill near Boylston Hall — not half the proportion (two volumes in 10,000) generally adopted as the index of good ventilation. No pollution can then be detected by the sense of smell.

<sup>8</sup> See experiments and observations on the summer ventilation and cooling of hospitals, Proceedings of the American Academy of Arts and Sciences, Vol. xxx.

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